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A Field of the Thermal Comfort in University Buildings in Thailand under Air Condition Room

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Abstract

The purpose of the present work was to determine the thermal comfort in university building in Thailand under air condition room. The students were tested in 8x9x3 m^3 test room set up with a 40,000 Btu/h, 2 unit split type air conditioner. The room air temperature was varied from 25, 26, 27 and 28 °C and in each temperature, was varied air speed 3 levels (low, medium and high). Thermal comfort survey using questionnaire base on ASHRAE thermal sensation scale and indoor environment monitoring i.e., temperature, air speed and relative humidity were conducted in varied conditions. The results showed that the most Thai students can accept temperature as high as 28°C by adjust air speed of air conditioner. In addition, from the equation PMV = $0.4708t_a - 1.0600v - 12.4597$ showed that the neutral temperature was increased with increasing of air speed. The results of this research can apply to conditioning systems design and control for comfortable feeling of students.

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Keywords: thermal comfort, predicted mean vote (PMV), actual sensation vote (ASV), air condition room,

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1. Introduction

Thermal comfort has been defined by Hensen as "a state in which there are no driving impulses to correct the environment by the behaviour" [1]. The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) defined it as "the condition of the mind in which satisfaction is expressed with the thermal environment" [2]. As such, it will be influenced by personal differences in mood, culture and other individual, organizational and social factors. Based on the above definitions, comfort is not a state condition, but rather a state of mind. The definition of thermal comfort leaves open as to what is meant by condition of mind or satisfaction, but it correctly emphasizes that the judgment of comfort is a cognitive process involving many inputs influenced by physical, physiological, psychological, and other factors[3].

Indoor thermal environments can significantly influence human health and comfort. In addition, thermal comfort is very important for architects and engineers to ensure comfort and health of occupant in the building [4]. Since the late 20th century, the PMV (Predicted Mean Vote) model developed by Fanger has been widely used throughout the world. Although the PMV model is based on the database of European and North American subjects, many researchers around the world have conducted experiments in climate chambers and have demonstrated its validity [5]. However, many researchers have not been applied in sub-tropical climates such as Thailand. Thailand is located in sub-tropical zone at latitude 13°18´N and longitude 100°27´E, according to the climatological method of classification, the weather of Thailand is classified as "Humid Subtropical Climate". For university buildings, indoor thermal environments influence on learning of students. In addition, comfortable of student will be able to increase learning. Thus, this work was to study of thermal comfort in university buildings in Thailand under air condition room.

Nomenclature

ASV	actual sensation vote
PMV	predicted mean vote
RH	relative humidity (%)
t_a	room air temperature (°C)
v	air speed (m/s)
M	metabolic heat production (W/m^2)
W	External work (W/m^2)
P_a	partial water vapour pressure (Pa)
f_{cl}	clothing area factor
t_{cl}	the outer surface temperature of clothed body (°C)
t_{mrt}	mean radiant temperature (°C)
h_c	heat transfer coefficient ($W/m^2 K$)

2. The predicted mean vote (PMV)

The PMV equations developed and suggested by Fanger has been used worldwide to predict and assess indoor thermal comfort in residential buildings, office, school etc. The PMV predicts the mean thermal sensation vote response of a large group of people according to the ASHRAE thermal sensation scale. Fanger's equations are used to calculate the PMV of a large group of subjects for a particular combination of air temperature, mean radiant temperature, relative humidity, air speed, metabolic rate, and clothing insulation [6] by the shown following equation:

$$PMV = (0.303\exp(-0.36M)+0.028)[(M-W)-3.05\times10^{-3}[5733 - 6.99(M - W) - P_a]-0.42[(M-W)-58.2] -1.73\times10^{-5}M(5867-P_a)-0.0014M(34-t_a)-3.96\times10^{-8} f_{cl} [(t_{cl} + 273.15)^4-(t_{mrt}+273.15)^4]-f_{cl}h_c(t_{cl} - t_a)] \quad (1)$$

3. Materials and method

The field measurements were performed in a room of size 8x9x3 m^3 and set up split type air conditioner with capacity of 40,000 Btu/h 2 units was hung on the top of the right wall are shown in Fig. 1. The room air temperature was varied from 25±0.5, 26±0.5, 27±0.5 and 28±0.5 °C and in each temperature, was varied air speed 3 levels (low, medium and high), which average air speed about 0.5, 0.7 and 0.9 m/s respectively. The questionnaire addressed the following areas: (i) background and personal information; (ii) current clothing garments; (iii) subjective thermal sensation vote (the Actual Sensation Vote, or ASV) based on the ASHRAE sensation scale, the evaluation had seven levels, from −3 to +3 (table 1). The total number of subjects was 660 persons, 424 males and 236 females, which they all wore normal clothes under uniform of university. The classroom was collected the indoor environment, i.e. temperature, relative humidity and air speed.

Table 1. ASHRAE sensation scale [2]

Thermal sensation	Cold	Cool	Slightly cool	Neutral	Slightly warm	Warm	Hot
Level	-3	-2	-1	0	+1	+3	+3

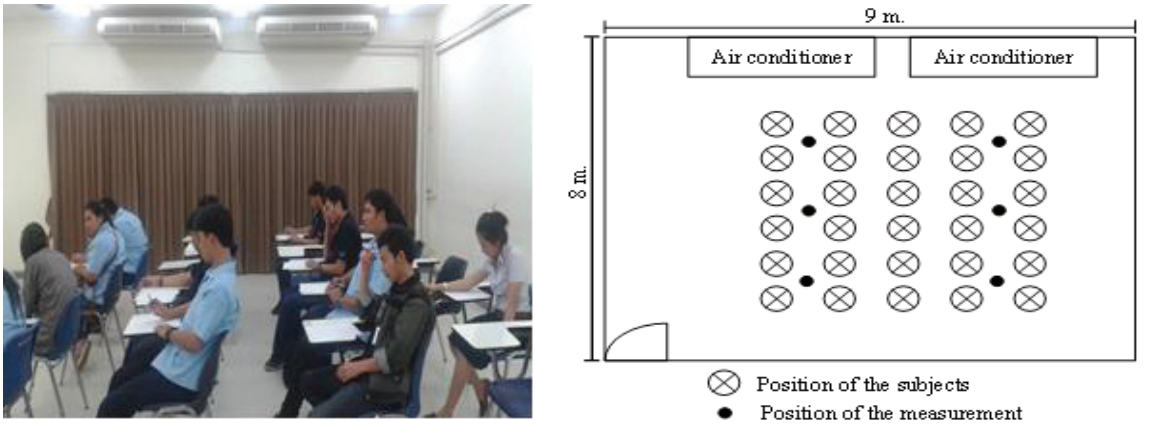

Fig. 1. (a) position and uniform of the subjects; (b) layout of the test room

4. Result and discussion

4.1. The general data

The general data of subjects, it was found that, The total numbers of test subjects were 660 (424 males and 236 females). Average age of subjects was 22 years, average weight was 64 kg. for male and 59 kg. for female, average height was 1.73 m. for male and 1.63 m. for female. The subjects have an average thermal resistance of clothing was 0.909 clo for male and 0.959 clo for female.

4.2. Actual sensation vote (ASV)

The percentages of actual sensation vote under room temperature air speed and relative humidity (50-80%) are shown in Table 2. It is seen that when the air speed at the same room air temperature was higher, the percent of actual sensation vote moved to the cool sensation vote side. While as the room air temperature was increased at the same air speed, the percent of sensation vote tends to move to the hot sensation vote side. Therefore, thermal comfort can be provided by increasing the air speed to compensate for the higher temperature.

Table 2. Percentage of actual sensation vote.

T (°C)	Air speed (m/s)	Percentage of actual sensation vote							Mean vote	Percent of -1 to +1
		-3	-2	-1	0	+1	+2	+3		
25±0.5	0.5	7	20	40	33				-1.0	73
	0.7	20	13	47	20				-1.3	67
	0.9	27	20	46	7				-1.7	53
26±0.5	0.5		7	47	33	13			-0.5	93
	0.7		13	40	40	7			-0.6	87
	0.9		13	54	33				-0.8	87
27±0.5	0.5		7	40	33	20			-0.4	93
	0.7		9	42	36	13			-0.5	91
	0.9		13	53	27	7			-0.7	87
28±0.5	0.5			7	27	66			0.6	100
	0.7			20	30	50			0.3	100
	0.9		7	53	20	20			-0.5	93

When consider the conditions for percent of thermal sensation vote between -1 to +1. It was found that room air temperature at 25°C and every air speed (0.5, 0.7 and 0.9 m/s), the percent of thermal sensation vote between -1 to +1 is equal to 53-73% and sensation vote remaining appear on cool sensation vote side. While room air temperature at 26°C, 27°C and every air speed, the percent of thermal sensation vote between -1 to +1 is equal to 87-93% and room air temperature at 28°C and every air speed is equal to 93-100%. In addition, all the room air temperature, when air speed was increased, the percent of -1 to +1 voted was decreased. If definition conditions for thermal comfort acceptability that more than 80% of subjects vote for thee thermal sensation of slightly cool, neutral and slightly warm or level from -1 to +1 [7]. It was found that the conditions at room air temperature 25°C and every air speed are not accepted. While the conditions at room air temperature 26, 27, 28°C and every air speed are accepted. Especially, at the room air temperature 28°C and air speed 0.5, 0.7 m/s, the percent of thermal sensation vote between -1 to +1 is equal to 100%. This can indicate that most Thai students can accept temperature as high as 28°C by adjust air speed of air conditioner. It is very interesting that the room air temperature can be set as high as 28°C with increasing of air speed instead of setting the temperature at 25°C as is the

normal set point in most buildings or recommendation of government. Consequently, it would help in reducing electricity consumption of air conditioners.

4.3. Thermal sensation equation

The predicted mean vote (PMV) were plotted under each air speed as shown in Fig. 2. The PMV at each point was obtained by sensation vote at the same room air temperature and air speed. It was seen that when the air speed increased, the neutral vote shifts to higher room air temperature.

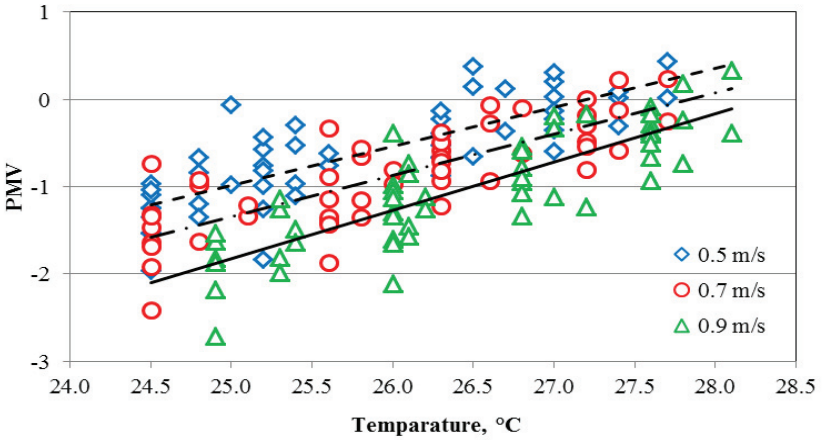

Fig. 2. PMV vs. room air temperature under various air speed.

To consider relationship between predicted mean vote (PMV) and air temperatur, air speed was applied to construct the PMV equation on linear regression form with the least square technique [7] . The obtained equation showed the relation between PMV and room air temperature and air speed as shown in Eq. (2)

$$PMV = 0.4708t_a - 1.0600v - 12.4597 \quad (2)$$

when t_a is room air temperature (°C) and v is air speed (m/s).

The neutral temperature for each air speed was calculated from Eq. (2) and shown in Table 3. It was found that at the air speed 0.5, 0.7 and 0.9 m/s, neutral temperature (PMV=0) was 27.6, 28.0 and 28.5°C respectively. One can say that the neutral temperature was increased with increasing of the air speed. In addition, the range of neutral temperature (27.6-28.5°C) at all air speed corresponded with thermal comfort acceptability of actual sensation vote (28±0.5°C), which is the most accepted temperature

Table 3. Neutral temperature (PMV=0) for different air speed.

Air speed (m/s)	0.5	0.7	0.9
Neutral temperature, °C	27.6	28.0	28.5

5. Conclusion

The study of thermal comfort in school buildings in Thailand air condition room was found that:

The air speed at the same room air temperature was higher, affect to actual sensation to the more comfortable. While as the room air temperature is increase at the same air speed, the actual sensation tends to the more hot sensation. Therefore, thermal comfort can be provided by increasing the air speed to compensate for the higher temperature.

The conditions room air temperature 26, 27, 28°C at air speed 0.5 to 0.9 are conditions accept, when definition conditions for thermal comfort acceptability that more than 80% of subjects vote for thermal sensation level from -1 to +1, while room air temperature at 25°C is conditions not accept.

The neutral temperature (PMV=0) increase with increasing of air speed. One can say that as the air speed increases, the neutral vote shifts to higher room air temperature. In addition, the range of neutral temperature at all air speed corresponded with thermal comfort acceptability of actual sensation vote (28±0.5°C), which is the most accepted temperature

The temperature set point was suggested to be increased to 28°C and adjust air speed from 0.5 to 0.9 m/s instead of setting the temperature at 25°C as is the normal set point in most buildings or recommendation of government. Consequently, it would help in reducing electricity consumption of air conditioners.

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